Task 3.4.5

WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Wetland Mitigation Replacement Ratios

an Annotated Bibliography

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WETLAND MITIGATION REPLACEMENT RATIOS:

An Annotated Bibliography

edited by

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Washington State Department of Ecology
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INTRODUCTION

Wetland Mitigation Replacement Ratios: An Annotated Bibliography is a compilation of abstracts dealing with wetlands mitigation designed to achieve a goal of "no net loss" of wetlands acreage and function. The entries in this document come from journal articles published in diverse fields: agriculture, engineering, fisheries, forestry, geology, landscape architecture, marine sciences, resource management, and wildlife biology. The bibliography also contains summaries of government publications from the federal, state, and local levels including government-funded research, guidance documents, and adopted or proposed wetlands conservation ordinances. Also included are summaries of symposia presentations.

OBJECTIVE

The objective was to create a compilation of citations which analyze the scientific basis for replacing lost wetland functions by creating new wetlands. Various political and scientific strategies and case histories are also included. Additional citations concern the protection of wetland functions and values from many different perspectives. Though extensive, this collection does not represent an exhaustive or exclusive listing of work conducted in each respective field concerning the protection of wetlands.

The intent of this collection is to assist landowners, planners, managers, developers, and politicians in the Pacific Northwest in understanding viable wetland ecosystems and the requirements for attaining "no net loss" of this diminishing resource.

METHODS

The literature search focused on technical information from journal articles, government documents, proceedings from conferences and symposiums, and research reports, rather than in text or general information books. On-line searches were conducted through AFSA, Enviroline, Water Resources, NTIS, Pollution, Life Sciences, AGRI COLA, and Biosis, as well as the collections at the following University of Washington libraries: Natural Sciences, Fisheries, Forestry, Engineering, and Architecture.

RESULTS AND DISCUSSION

Whenever available, the authors' original abstracts appear. Information added to the authors' abstract by the editors is provided in brackets, [ ], following the original abstract. For those citations without abstracts, a synthesis of material was undertaken by the editors.

The source of each summary is noted prior to each abstract: a single * denotes the author's abstract in the citation, a double ** denotes an editors' synthesis of the material.

A complete list of articles reviewed appears at the end of the bibliography; bold-faced references are those which are included in the annotated bibliography. Exclusion of reviewed articles from the annotated bibliography is entirely due to time and budgetary constraints; no lack of scientific merit or applicability should be inferred from these or other omissions.

Many of the citations have been included in a companion summary report:

Castelle, A.J., C. Conolly, M. Emers, E.D. Metz, S. Meyer, M. Witter, S. Mauermann, M. Bentley, D. Sheldon, and D. Dole. 1992. Wetland Mitigation Replacement Ratios: Defining Equivalency. Adolfson Associates, Inc., for Shorelands and Coastal Management Program, Washington State Department of Ecology, Olympia, Publ. No. 92-08.

COMMENTS

All comments on this document and information on additional citations concerning wetland replacement ratios are welcome. Written suggestions and inquiries should be made to:

Washington State Department of Ecology
Shorelands and Coastal Zone Management Program
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P.O. Box 47600
Olympia, Washington 98504-7600

CITATION

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Adamus, P. R., and L.T. Stockwell. 1983. A Method for Wetland Functional Assessment, Vol. 1. Federal Highway Administration Rep. No. FHWA-IP-82-23.

Abstract: *

The manual presents a state-of-the-art review of wetland functions. Functions covered include groundwater recharge and discharge, flood storage and desynchronization, shoreline anchoring and dissipation of erosive forces, sediment trapping, nutrient retention and removal, food chain support (detrital export), habitat for fish and wildlife, and active and passive recreation. The manual covers all wetland types in the 48 conterminous states, and uses the U.S. Fish and Wildlife Service definition and classification system. It examines the validity, interactions, and possible significance thresholds for the functions, as well as documenting their underlying processes. With appropriate qualifying information, wetland types are ranked for each function. Wetland types ideal for each function are identified and illustrated. Potential impacts of highways upon each function are described and, where available, possible thresholds are given. Factors which regulate impact magnitude, such as location, design, watershed erodibility, flushing capacity, basin morphology, biotic sensitivity (resistance and resilience), recovery capacity, and refugia, are explained. Cumulative impacts and social factors affecting wetland significance are discussed. Effects of the following factors on wetland function are documented: contiguity, shape, fetch, surface area, area of watershed and drainage area, stream order, gradient, land cover, soils, depositional environment, climate, wetland system, vegetation form, substrate, salinity, pH, hydroperiod, water level fluctuations, tidal range, scouring, velocity, depth, width, circulation, pool-riffle ratio, vegetation density, flow pattern, interspersion, human disturbance, turbidity, alkalinity, dissolved oxygen, temperature, and biotic diversity.

Adamus, P.R., E.J. Clarain, Jr., R.D. Smith, and R.E. Young. 1987. Wetland Evaluation Technique (WET); Volume II: Methodology. Operational Draft Technical Report Y-87-__, U.S. Army Engineer Waterway Experiment Station, Vicksburg, MS.

Abstract: *

This manual outlines a Wetland Evaluation Technique (WET) for the assessment of wetland functions and values. WET is a revision of the method developed for the Federal Highway Administration (FWHA) that has often been referred to as the "Federal Highway Method" or the "Adamus Method."

Wetland functions are the physical, chemical, and biological characteristics of a wetland. Wetland values are those characteristics that are beneficial to society. WET evaluates the following functions and values: ground water recharge, ground water discharge, floodflow alteration, sediment stabilization, sediment/toxicant retention, nutrient removal/transformation, production export, wildlife diversity

/abundance, aquatic diversity/abundance, uniqueness/heritage, and recreation. WET evaluates functions and values in terms of social significance, effectiveness, and opportunity. Social significance assesses the value of a wetland to society in terms of its special designations, potential economic value, and strategic location. Effectiveness assesses the capability of a wetland to perform a function because of its physical, chemical or biological characteristics. Opportunity assesses the opportunity of a wetland to perform a function to its level of capability.

WET evaluates functions and values by characterizing the wetland in terms of predictors. Predictors are simple, or integrated, variables that are believed to correlate with the physical, chemical, and biological characteristics of the wetland and its surroundings. Responses to questions concerning the predictors are analyzed in a series of interpretation keys that reflect the relationship between predictors and wetland functions or values as defined in the technical literature. Interpretation keys assign a qualitative probability rating of HIGH, MODERATE, or LOW to each function and value in terms of social significance, effectiveness, and opportunity.

WET also assesses the suitability of wetland habitat for 14 waterfowl species groups, 4 freshwater fish species groups, 120 species of wetland-dependent birds, 133 species of saltwater fish and invertebrates, and 90 species of freshwater fish. WET does not assess the suitability of wetland habitats for many important wildlife resources (e.g., furbearers, game mammals). Other methods must be used for these species.

WET was designed primarily for conducting an initial, rapid assessment of wetland functions and values. WET can also be applied in a variety of other situations including: (1) comparison of different wetlands, (2) selection of priorities for wetland acquisition or detailed, site-specific research, (3) selection of priority wetlands for Advanced Identification, (4) identification of options for conditioning of permits, (5) determination of the effects of preproject or postproject activities on wetland functions and values, and (6) comparison of created or restored wetlands with reference or preimpact wetlands for mitigation purposes.

Broome, S.W., E.D. Seneca, and W.W. Woodhouse, Jr.. Tidal salt marsh restoration. 1988. Aquatic Botany 32:1-22.

Abstract: *
Coastal salt marshes occur in the intertidal zone of moderate to low energy shorelines along estuaries, bays and tidal rivers. They have ecological value in primary production, nutrient cycling, as habitat for fish, birds, and other wildlife and in stabilizing shorelines. Disturbance by development activities has resulted in the destruction or degradation of many marshes. Awareness of this loss by scientists and the public has led to an interest in restoration or creation of marshes

to enhance estuarine ecosystems. Recovery of marshes after human perturbation such as dredging, discharges of wastes and spillage of petroleum products or other toxic chemicals is often slow under natural conditions and can be accelerated by replanting vegetation. The basic techniques and procedures have been worked out for the propagation of several marsh angiosperms. Factors which affect successful revegetation include elevation of the site in relation to tidal regime, slope, exposure to wave action, soil chemical and physical characteristics, nutrient supply, salinity and availability of viable propagules of the appropriate plant species. Marsh restoration technology has been applied at a variety of locations to vegetate intertidal dredged material disposal sites, stabilize shorelines, mitigate damage to natural marshes and to revegetate one marsh destroyed by an oil spill. Contractual services for marsh establishment are now available in some regions. Further research is needed to determine the success of marsh restoration and creation in terms of ecological function, including the faunal component.

Carothers, S.W., G.S. Mills, and R.R. Johnson. 1990. The Creation and Restoration of Riparian Habitat in Southwestern Arid and Semi-Arid Regions. pp. 351-366. *In*: J.A. Kusler and M.E. Kentula (eds.), Wetlands Creation and Restoration: The Status of the Science. Island Press, Washington D.C.

Abstract: *
Though the literature on characteristics, values, and functions of riparian habitats in Southwestern arid and semi-arid regions is fairly extensive, few papers that pertain to its creation or restoration are available. Very few creation and restoration projects are more than ten years old and most large projects have been undertaken in the last five years. Because they are so recent, evaluations of successes and failures are based on short-term results; long-term survival and growth rates are, as yet, unknown.'

In most cases, creation and restoration projects have involved the planting of vegetation and not the creation of conditions suitable for the natural regeneration of riparian habitats. Many planted riparian forests do not reproduce and their longevity is therefore determined by the lifespan of the individual trees. Mitigation provided by such forests is temporary.

Important considerations for riparian creation or restoration projects in the Southwest include:

1. Depth of water table.
2. Soil salinity and texture.
3. Amount and frequency of irrigation.
4. Effects of rising and dropping water tables on planted trees.
5. Protection from rodent and rabbit predation.

6. Elimination of competing herbaceous weeds.
7. Protection from vandalism, off-road vehicles, and livestock.
8. Monitoring of growth rates as well as survival.
9. Project design flexible enough to allow for major modifications.

Because the creation and restoration of riparian habitats in the Southwest is new and mostly experimental, more information is needed for virtually every aspect of revegetation. Two major questions that need to be answered are whether planted trees survive for more than a few years and reach expected size, and what ranges of planting parameters are most cost-effective. Specific information needs include the identification of: the most suitable watering regimes; suitable soil conditions for various tree species; long-term survival and growth rates; and effects of variable water table levels on planted trees.

Carter, V. 1986. An Overview of the Hydrologic Concerns Related to Wetlands in the United States. Canadian J. Botany 64:364-374.

Abstract: *
There is a tremendous diversity in wetland types and wetland vegetation in the United States, caused primarily by regional, geologic, topographic, and climatic differences. Wetland hydrology, a primary driving force influencing wetland ecology, development, and persistence, is as yet poorly understood. The interaction between groundwater and surface water and the discharge-recharge relationships in wetlands affect water quality and nutrient budgets as well as vegetative composition. Hydrologic considerations necessary for an improved understanding of wetland ecology include detailed water budgets, water chemistry, water regime, and boundary conditions. Wetland values are often based on perceived wetland functions. These hydrologic functions include *(i)* flood storage and flood-peak desynchronization, *(ii)* recharge and discharge, *(iii)* base flow and estuarine water balance, and *(iv)* water-quality regulation. Expanded research and basic data collection focussed on wetland hydrology and its relation to wetland ecology are needed to identify and quantify the hydrologic functions of wetlands.

Coats, R., M. Swanson, and P. Williams. 1989. Hydrologic Analysis for Coastal Wetland Restoration. Environmental Management 13:715-727.

Abstract: *
Increasing recognition of the value of tidal wetlands has led to interest in how to restore and enhance areas that have been modified by human activity. The policy of recognizing restoration or enhancement as mitigation for destruction of other wetlands is controversial. Once policy questions are separated from technical questions, the steps in a successful project are straightforward. A key element in the design of a successful project is quantitative hydraulic and hydrologic analysis of alternatives. Restoration projects at two sites in California used a combination of

empirical geomorphic relationships, numerical modeling, and verification with field observations. Experience with these and other wetland restoration projects indicates the importance of long-term postproject monitoring, inspection, and maintenance.

D'Avanzo, C. 1990. Long-Term Evaluation of Wetland Creation Projects. pp. 487-496. *In*: J.A. Kusler and M.E. Kentula (eds.), Wetland Creation and Restoration: The Status of the Science, Part 2: Perspectives. Island Press, Washington, D.C.

Abstract:

Long-term success of wetland restoration and creation projects may be quite different from short-term success. In this chapter six criteria are used to evaluate the long-term success of more than 100 artificial wetland projects reported in the literature. Results from numerous U.S. Army Corps of Engineers' dredged material stabilization projects demonstrate the importance of long-term monitoring and increasing long-term as well as short-term success. Several studies reviewing wetland creations are also used to demonstrate problems with projects in both the short and long-term.

The long-term evaluation of artificial wetlands is very difficult because wetlands are created for a variety of purposes. We know little about basic aspects of many wetland systems, "succession" in wetlands is less straightforward than previously assumed, and it is difficult to generalize from one wetland type to another. There is a striking range of opinions about the success of wetlands that have been created. On the one hand, the U.S. Army Corps of Engineers' dredged material stabilization program exemplifies artificial wetland projects that appear successful over a decade or more. Several types of criteria including vegetation characteristics, soil chemistry, and animal studies suggest that several dredged material wetlands are becoming similar to reference wetlands with time. But, some wetlands characteristics (soil carbon) may require many years to reach natural levels.

In contrast, a great many other artificial wetland projects are problematic or failures. Reasons for failures include improper hydrology, erosion, herbivory, and invasion by upland plants. Many projects have never been evaluated so their permanence is not known, and a disturbing number of required projects have never been created.

In evaluating projects with regard to persistence (long-term success) of the created wetlands, the following points are especially important: 10 1/2 years of monitoring is too short; evaluations over as long a period of time as possible (10-20 years) are desirable; 2) vegetation characteristics are useful but do not necessarily indicate function; at a minimum, several parameters should be used (e.g., belowground/aboveground biomass comparisons); 3) chemical/physical aspects of

wetland soils are also useful in evaluating trends in created sites; 4) local reference wetlands are critical for comparative purposes; and 5) some wetlands should be created with great caution because they have failed in the past (e.g., high salt marsh in the northeast) or because we know little about these wetland types (e.g., forested wetlands).

Davis, A.A. 1989. DER Wetlands Protection Action Plan. Water Pollution Control Association of Pennsylvania Magazine 22:18-22.

Abstract : *
The goal of the Pennsylvania DER (Department of Environmental Resources) wetlands protection policy is to prevent destruction, degradation, or significant impact to wetlands where practicable alternatives exist, and to minimize impacts or replace wetlands where impacts are unavoidable. DER will adopt the triple parameter approach found in the EPA Wetland Identification and Delineation Manual to develop means of identifying and evaluating wetlands early in the development process. Mitigation standards will be established to replace the wetlands values which are lost or degraded. DER proposes to establish a 100 ft. impact area around all wetlands and a 300 ft. impact area around all "exceptional value" wetlands.

Décamps, H., F. Fornier, R.J. Naiman, and R.C. Petersen, Jr. 1990. An International Research Effort on Land/Inland Water Ecotones in Landscape Management and Restoration 1990-1996. Ambio 19(3):175-176.

As a result of meetings and workshops at Tolouse, France in 1986 and at the Hungarian Academy of Sciences in 1988 a joint Unesco and Man and the Biosphere research effort was undertaken to determine the management options for the conservation and restoration of land/inland water ecotones through increased understanding of ecological processes. The objectives of the program are 1) to identify the gaps in our present knowledge and understanding; 2) to understand the role of ecological processes within ecotones in determining landscape patterns; 3) to develop management plans to conserve ecotones and to address detrimental environmental practices; 4) to develop a collaborative research project on the theme of recovery and restoration of degraded ecotones occurring at the terrestrial-aquatic interface. The main research activities will concentrate on 1) ecotone functions, including edge effects, community composition and structure, hydrologic and nutrient regimes; 2) relationships between ecotones and adjacent systems; 3) management and human investment.

Edwards, E.A., D.A. Krieger, M. Bacteller, and O.E. Maughan. 1982. Habitat Suitability Index Models: Black Crappie. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.6.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Black crappies were found to be susceptible to turbidity, to require abundant cover for growth and reproduction, in the form of aquatic vegetation, and submerged trees, brush or instream objects. Low velocity waters were preferred in such areas as pools and backwaters.]

Erwin, K.L. 1990. Freshwater Marsh Creation and Restoration in the Southeast. pp. 233-266. *In*: J.A. Kusler and M.E. Kentula (eds.), Wetland Creation and Restoration: The Status of the Science, Part 2: Perspectives. Island Press, Washington, D.C.

Abstract: *
Freshwater marsh habitat has been created or restored in the southeast to mitigate the environmental impacts associated with development activity and to provide enhancement of water quality. These projects vary in size, design, and function, and are inadequately discussed in the literature. There is a question of whether agency-mandated mitigation projects have actually been implemented and to what extent these created freshwater marshes are providing the desired wetland functions.

Key elements to successfully constructing a functional freshwater marsh system include: (1) realistic goals and measurable success criteria; (2) proper pre-construction design evaluation including a hydrological analysis; (3) contour design; (4) construction technique; (5) proper water quality; (6) compatibility of adjacent existing and future land uses; (7) appropriate substrate characteristics; (8) re-vegetation techniques; (9) re-introduction of fauna; (10) upland buffers and protective structures; (11) supervision by an experienced professional; (12) post-construction long term management plan; and (13) monitoring and reporting criteria.

The monitoring required must be adequate in scope to determine the success or failure to meet project goals. A typical monitoring plan for a created freshwater marsh should include: (1) a post-construction, pre-planting survey of project contours and elevations; (2) ground and surface water elevation data collection; (3)

water quality data collection; (4) biological monitoring including, but not limited to, fish and macroinvertebrate data collection; (5) evaluation of vegetation species diversity, percent cover, and frequency; and (6) wildlife utilization.

Critical information gaps and research needs can be divided into the following categories: (1) site selection and design; (2) project construction techniques; (3) comparative studies of the biological communities and processes in created and natural systems; and (4) the role of uplands and transitional habitats.

Fonseca, M.S. 1990. Regional Analysis of the Creation and Restoration of Seagrass Systems. pp. 171-194. *In*: J.A. Kusler and M.E. Kentula (eds.), Wetlands Creation and Restoration: The Status of the Science. Island Press, Washington D.C.

Abstract: *
Seagrasses occur in most coastal, marine regions and are highly productive habitats. They are not a traditional wetland type but do meet the criteria for protection of aquatic habitat under Section 404 of the Clean Water Act. Including seagrass acreage would increase national wetland acreage approximately 17 percent. Seagrasses are described under six Ecoregions for management. Adequate water clarity for light transmission is required for restoration and survival of seagrass meadows.

Goals and performance guidelines for seagrass restoration and creation projects have historically been inappropriate. Consequently, seagrass restoration has never prevented a net loss in habitat. Suggested goals to prevent such losses include: development of persistent cover, generation of equivalent acreage or increased acreage, replacement with the same seagrass species, and restoration of secondary (faunal) production. These goals are to be differentiated from measures of density and percent survival. Monitoring for cover and persistence should continue for 3 years.

Site selection is a complex problem. The primary choice for restoration sites should be areas previously impacted or lost. The secondary choices should be perturbed aquatic areas irrespective of their previous plant community or uplands which can be excavated and converted to seagrass habitat. Population growth rate determines the species chosen for the restoration. Inclusion of specific conditions in the permit will enhance the probability of project success.

Research needs include: defining functional restoration, compiling population growth and coverage rates by Ecoregion, examining the resource role of mixed species plantings, determining the impact of substituting pioneer for climax species on faunal composition and abundance, evaluating the substitution of other species (e.g., mangroves, salt marshes) on cumulative damage to habitat resources when

suitable sites cannot be found for seagrass planting, developing culture techniques for propagule development, exploring transplant optimization techniques such as the use of fertilizers, and delineating seagrass habitat boundaries. Most important would be the implementation of a consistent policy on seagrass restoration and management among resource agencies wherein restoration technique, monitoring, and performance and compliance guidelines would be standardized.

Frenkel, R.E. and J.C. Morlan. 1990. Restoration of the Salmon River Salt Marshes: Retrospect and Prospect. Final Report to the U.S. Environmental Protection Agency. Dept. of Geosciences, Oregon State University, Corvallis, Oregon.

Abstract: *
In 1978 the U.S. Forest Service breached a dike on the north shore of the Salmon River estuary to reestablish a natural salt marsh in a diked pasture. Diane L. Mitchell, a graduate student at Oregon State University, initiated a detailed study of the restoration of the salt marsh ecosystem in 1977. Her work was completed in 1981. In this report, we summarize the status of the restoration in 1988, eleven years after dike removal, and discuss prospects for total restoration to conditions prevailing prior to human alterations.

We assessed restoration of a 21 ha diked pasture in the Salmon River estuary to a naturally functioning estuarine salt marsh in 1988, eleven years after partial dike removal in 1978. Diane Mitchell (1981) collected base line data, established an intensive sampling system of permanent plots in the diked pasture and flanking "intact" control marshes, and analyzed restoration progress from 1978 to 1980. Our report continues Mitchell's earlier research by evaluating the composition, structure, function, and long term prospects for the restored wetland.

Garbisch, E.W., Jr. 1977. Recent and Planned Marsh Establishment Work Throughout the Contiguous United States--A Survey and Basic Guidelines. Contr. Rep. D-77-3 U.S. Army Eng. Waterways Exp. Sta., Vicksburg, Mississippi.

Abstract: *
Information on deliberate marsh establishment work that is planned, underway, or completed throughout the contiguous United States 1970-1976 has been identified excluding WES, through (1) literature review, (2) interviewing people who, during the period of May 1975 through January 1977, have become known to be potential sources of pertinent information, and, (3) the completion of distributed information request forms by various correspondents.

Excluding U.S. Army Engineer Waterways Experiment Station (WES) projects currently underway, marsh establishment projects at 105 district locations have been

completed for at least 1 year and 14 projects are planned for the immediate future. Out of the 105 completed or continuing marsh establishment projects, 9 were totally unsuccessful (due to vandalism, Canada geese eat-out, wave exposure too severe for seeding, or site surface elevations too low for seeding). Variation encountered in projects included 18 that existed in freshwater or nearly freshwater locations, 68 on the east coast, 17 on the gulf coast, 8 on the west coast, and 12 inland; 59 were purely experimental, as opposed to applied or partly so. From information received and collated, practical guidelines for site preparation, marsh establishment, and site management and maintenance were developed and are discussed. The two most important factors for preparing a site for marsh establishment were surface slopes and surface elevations. Within the tidal zone, surface slopes would be developed such that they exhibit reasonable stabilities in the absence of vegetative cover. Surface elevations must be carefully considered in the design and planning of a project and tied in with the various zones of marsh types existing in the region. Surface elevations are most important and their acceptable tolerances most stringent in areas subject to tidal amplitudes of 2 ft or less. Long term consolidation of fine sediment types is not considered of practical importance in achieving final surface elevations within acceptable tolerances. Close coordination between the site preparation and the marsh establishment stages of a project in terms of time of year is considered important; however, the use of nursery plant stock may alleviate the consequence of unacceptable marsh establishment because of unavoidable delays in the site preparation.

All aspects of marsh establishment must be an integral part of the design and planning the total project. Selection of the plant species to be used in the various available elevation zones at the site must be governed by (1) the plant species known to exist within these zones in natural marshes in the region, (2) the objectives of the project, (3) the relative growth rates and sediment stabilizing capabilities of the candidate plants, and (4) the relative food value ratings of the candidate plants stock that can be successfully used at the site will depend upon (1) the available surface elevations at the site, (2) the exposure of the site to various physical stresses, and (3) the time of planting.

Properly developed nursery stock is considered superior to all other types for sites or sections of sites subjected to high wave and debris deposition stresses and for summer, fall, and winter plantings. Marsh establishment by seeding is considered feasible only in the spring, in sheltered or confined areas, and at elevations above mean tidal level (MTL) (preferably the upper 20% of the mean tidal range). Although exceptions are discussed, a rule of thumb is that increasing the maturity of nursery transplant materials upon decreasing the elevations in the tidal zone will lead to the greatest survival of transplants and the best overall plant establishment. Transplant spacing and fertilization requirements are discussed. Although fertilizations should be conducted for all marsh establishment work in sand sediments, the need for such fertilizations in other sediment types (silt-clay) is not readily determined.

Three principal maintenance and management requirements for marsh establishment determined by the study are (1) removal of debris and litter depositions, (2) protection against waterfowl depredation, and (3) fertilization. During the growing season, particularly for late spring and summer plants, algae, submerged aquatic plants, free-floating aquatic plants, and/or sundry debris that have been washed and deposited throughout the developing marsh, may have to be periodically removed. Otherwise, the affected plants may be seriously impaired. Depending upon the prevailing populations of geese, and to a lesser extent other wildlife, marsh establishment sites may have to be protected by enclosures or other effective devices. Areas of marsh establishment sites subject to extended periods of high wave stress may require annual maintenance fertilizations to prevent the marsh from succumbing to the stress.

Garbisch, E.W., Jr. 1986. Highways and Wetlands: Compensating Wetland Losses. Rpt. No. FHWA-IP-86-22. U.S. Department of Transportation, Federal Highway Administration, Office of Research and Development, Washington, D.C.

Abstract: *

This Implementation Package is a practical guide for the creation and restoration of wetlands. It provides concepts, methods and general specifications for compensating unavoidable wetland losses in a cost effective manner. The manual includes guidance for wetland establishment and enhancement and provides information for the conceptual design of wetland systems.

The site-specific nature of wetland compensation measures precludes giving detailed instructions and specifications for the establishment and enhancement of wetlands. Although much work on the establishment of wetlands has been published within the past decade (Appendix B), the state-of-the-art is still primitive. Consequently, this manual is far from the last word. It is a beginning and a lot is left to the best judgement of the users.

Hollands G.G. 1990. Regional Analysis of the Creation and Restoration of Kettle and Pothole Wetlands. pp. 281-298. *In*: J.A. Kusler and M.E. Kentula (eds.), Wetlands Creation and Restoration: The Status of the Science. Island Press, Washington D.C.

Abstract: *

Kettles are topographic basins created by a variety of glacial processes and occur randomly throughout glaciated regions. They are associated with both permeable and impermeable deposits. Kettle wetlands can have complex hydrology but are divided into two general hydrologic types: those having no inlet or outlet streams, and those associated with surface water streams. Kettle ground water hydrology is generally described as that associated with permeable deposits where ground water is an important part of their water balance, and that associated with plow permeability deposits where ground water is not the dominant element of their water balance. Complex relationships of surface water, ground water, water chemistry and other hydrologic elements combine to create water balances. This has been documented in the Prairie Potholes region where site specific hydrologic research has been conducted. Specialized soils and vegetation occur in kettles with unique hydrology. Kettle wetlands have wetland functions similar to other freshwater wetland types.

Kettle-like wetlands have been created by man for a variety of purposes. Creation of kettles for mitigation has occurred at only a few locations. Renovation of Prairie Potholes has occurred with success.

Creating kettle wetlands is similar to other types of freshwater wetland creation, except where unique vegetation and hydrology are involved and replication may be a complex, technical effort. Identification of limiting factors is critical to wetland creation. Typical factors important to kettle wetlands are: surface water hydrology, ground water hydrology, stratigraphy, soils, and water chemistry. Depending upon the goals of the project, other limiting factors may include: nuisance animals, long term maintenance/monitoring, lack of funds, and disposals of excavated soil.

The primary concern in creating kettle wetlands is the establishment of the proper hydrology. This normally requires mid-course corrections in design during construction to establish proper post-construction hydrology.

Critical research needs include studies on microstratigraphy, geochemical processes, the properties of organic soil, and the details of hydrology.

Hook, D.D., W.H. McKee, Jr., H.K. Smith, J. Gregory, V.G. Burrell, Jr., M.R. DeVoe, R.E. Sojka, S. Gilbert, R. Banks, L.H. Stolzy, C. Brooks, T.D. Matthews, and T.H. Shear. 1988. The Ecology and Management of Wetlands. Volume 2. Management, Use, and Value of Wetlands. Timber Press, Portland, Oregon. 986 pages.

Abstract : **
This two-volume work presents selected papers from a symposium on wetlands organized by the International Society of Anaerobiosis, held in June, 1986 in Charleston, South Carolina. Contributors are international authorities from all over the world, principally the USA and Europe. Volume 2 covers applied topics such as agricultural use, restoration and regulation, use for forestry, fisheries and wildlife, and evaluation methods.

Josselyn, M., J. Zedler, and T. Griswold. 1990. Wetland Mitigation Along the Pacific Coast of the United States. pp. 3-36. *In*: J.A. Kusler and M.E. Kentula (eds.), Wetland Creation and Restoration: The Status of the Science, Part 2: Perspectives. Island Press, Washington, D.C.

Abstract: *

Mitigation to compensate for coastal wetland losses has taken place under federal and state permit policies for over 15 years. As a result, a substantial database has developed in the scientific and governmental literature on which to base recommendations for improvement in mitigation practice. The purpose of this chapter is to review the status of wetland mitigation along the Pacific coast based on the available literature and more recent evaluations.

An important distinction must be made when evaluating the effectiveness of mitigation in offsetting wetland losses. Many projects have failed due to lack of compliance with permit requirements, e.g., have never been implemented or were completed without regard to permit specifications. On the other hand, mitigation effectiveness for those projects which have been completed is more difficult to assess. Functional success involves evaluation not only based on objectives, but on our knowledge of wetland hydrology and ecology, fields of science which have only recently received significant attention. Given the rarity of Pacific coastal wetlands and the substantial losses which occurred prior to the Clean Water Act, mitigation must be considered only after avoidance measures are thoroughly considered.

Mitigation for Pacific coastal wetlands is not a "cookbook" exercise. The concept that wetlands are simple ecosystems that can be re-created with little forethought must be rejected. Hydrologic characteristics of a mitigation site are especially important as they structure the possible wetland habitats that can be created. Within the Pacific coastal zone, four general hydrological type occur:

- Wetlands associated with small coastal rivers or lagoons, often subject to sandbar closure,

- Wetlands associated with major estuaries and coastal embayments,

- Wetlands associated with rivers, and

- Non-tidal wetlands such as vernal pools.

Within each of these broad categories, specific opportunities and constraints must be considered prior to approving mitigation proposals. In-kind habitat replacement will not be feasible if mitigation is proposed across types, given their significant differences. Most importantly, watershed management must also be considered

within each hydrologic type as an important criteria in evaluating the potential success of a mitigation proposal.

Permit applications must include information on project goals and habitat objectives. Goals and objectives must be specific and stated within a time frame that can be monitored. In addition, a number of elements need to be included within mitigation proposals:

- Description of existing conditions including information on site history, topography, hydrology, sedimentation, soil types, presence of existing wetlands and wildlife, and adjacent land uses,

- Description of proposed hydrological conditions as related to the specific requirements of the wetland vegetation and habitat desired,

- Means by which mitigation site constraints such as subsidence, excessive sedimentation, and poor substrate are to be ameliorated,

- Planting procedures, especially within tidal sites with poor soils or limited seed recruitment. If planting is not required, the period of time after implementation during which full plant establishment is expected should be determined and justified in light of the habitat lost,

- Determination of appropriate buffers that provide protection to the wetland,

- Enforceable procedures to provide construction project oversight by qualified engineers, or hydrologists,

- Monitoring programs to allow enforcement of permit requirements and provide further information on the effectiveness of mitigation projects as a means to increase wetland resources rather than simply to offset losses.

Outside of site specific review, resource agencies must assess the long-term implications of individual permit approvals. Re-appraisal should be based on detailed analysis contained within accessible database files. Such appraisal can provide important information on regional trends and means by which mitigation can be re-directed to better serve fish and wildlife needs.

Kobriger, N.P., T.V. Dupuis, W.A. Kreutzberger, F. Strarns, G. Guntenspergen, and J. Keough. 1983. Guidelines for Management of Highway Runoff on Wetlands. AASHTO, Transportation Research Board, National Research Council, Washington, D.C. Report #264.

Abstract : *
The guidelines contained in this report for the management of highway runoff on wetlands cover many functions: wetland creation and maintenance, wildlife considerations, regulatory controls, wetland monitoring, modeling techniques, and highway construction, design, and maintenance practices affecting the relationship between highway runoff and wetlands. The report also addresses the feasibility of using certain wetland types for mitigating the effects of highway runoff on wetlands, and it summarizes a companion agency document, "The Effects of Highway Runoff on Wetlands," that more fully covers the interaction of wetland systems and highway runoff on wetlands. Additionally, the report includes an extensive bibliography with entries grouped by major subject area.

Krieger, D.A., J.W. Terrell, and P.C. Nelson. 1983 Habitat Suitability Information: Yellow Perch. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.55.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Yellow perch are associated with the littoral zone of lakes and reservoirs where shoreline vegetation is present (optimally 25% cover). This vegetation provides for both cover and spawning. Riverine habitat for yellow perch requires pools and slack water areas along a vegetated shoreline edge. High turbidity lowers visibility of prey and restricts zooplankton to the upper water column where they are unavailable for the juvenile yellow perch to eat. The high summer temperature lethal to the yellow perch is 32.2 °C (90°F).]

Lovejoy, T.E. and D.C. Oren. 1981. The Minimum Critical Size of Ecosystems. pp. 7-12. *In*: R. L. Burgess and D. M. Sharpe (eds.), Forest Island Dynamics in Man-Dominated Landscapes. Ecological Studies #41. Springer-Verlag: New York. 310 pp.

Abstract: **
The authors conclude that because natural areas are being fragmented by development, the basic theory of island biogeography may be applied towards non-island environments in order to establish the minimum critical size of ecosystems to maintain biological integrity. The report suggests that the size of habitat reserves

should be dictated by the goal of maintaining a functioning ecosystem, not strictly by species numbers. The dynamics of an ecosystem may prevent managing the biological integrity of reserves at 100%, even with additional safety factors.

Maestri, B. and B.N. Lord (eds.). 1987. Guide for Mitigation of Highway Stormwater Runoff Pollution. Science for the Total Environment 59:467-476.

Abstract : *
Guidelines to reduce the impacts of highway stormwater runoff have been developed to address both management practices and mitigation measures. The research is a part of the Federal Highway Administration's ongoing program, "Nonpoint Source Pollution from Highway Stormwater." Practical, effective, and implementable mitigation methods have been identified, based upon a synthesis of current practices and an extensive literature review. An important output of this research was the identification of impractical or ineffective measures. The research also identified general design principles and practices that are an integral part of good engineering. The outputs are relatively low cost to implement and can be incorporated into current designs and operations. Specific design guidelines are provided for vegetative controls, detention basins, infiltration, and wetlands. Examples of highway applications of management practices and mitigation measures, singly and in combination, are presented.

Martinez-Taberner, A., G. Moya, G. Ramon, and V. Forteza. 1990. Limnological Criteria for the Rehabilitation of a Coastal Marsh. The Albufera of Majorca, Balearic Islands. Ambio 19:21-27.

Abstract: *
Mediterranean coastal zones have turned into popular leisure centers visited mainly by northern European tourists. The hotel industry has produced an economic boom in what were relatively undisturbed areas. Due to this fact studies dealing with the management and preservation or rehabilitation of natural zones are essential to balance social and economic development. The aim is to preserve the natural environment and landscape in order to retain its appeal for visitors. The present work on the rehabilitation of the Albufera of Majorca is an area within this context. The geomorphological evolution of the Albufera of Majorca is discussed and the principal environmental components are analyzed. On this basis major criteria for rehabilitation are proposed; (1) To preserve the present dynamics of the lagoons and eliminate factors distributing lotic environments. (2) To increase open water zones by progressively reintroducing preexisting lagoons in order to achieve an increase in food resources and in the number of habitats. (3) To change the present water circulation pattern fractalizing its route, i.e., allowing water to spread throughout the Albufera thereby decreasing its renewal rate. (4) To avoid environmental homogeneity and to attempt a smoothening out of the

environmental gradient so that it can be occupied by a large number of species with different environmental tolerances.

Nelson, R.W. and W.J. Logan. 1984. Policy on Wetland Impact Mitigation. Environmental International 10:9-19.

Abstract: *
Important policy issues concerning the mitigation of impacts from construction and development affecting wetlands are under examination by the U.S. Congressional Office of Technology Assessment, the Environment and Public Works Committee of the U.S. Senate, and the National Wetlands Technical Council. The issues divide into two main parts: (1) how the current strategy to simplify federal regulation of wetlands is limiting the success of mitigation; and (2) how to change the present strategy for mitigation under the U.S. Clean Water Act, if at all. Requirements for site-specific analysis of impacts and their mitigation requirements are being replaced by simple, uniform national guidelines on impact mitigation; these guidelines are designed to streamline the regulatory process in which the proposed activities typically generate only minor impacts. This trend ignores how the intrinsic values of the affected wetland modify the actual severity of impact. A change in regulatory strategy may be necessary so that the efforts at impact mitigation are scaled to wetland values as well as the magnitude of adverse effects normally expected with particular activities.

Newton, R.B. 1989. The Effects of Stormwater Surface Runoff on Freshwater Wetlands: A Review of the Literature and Annotated Bibliography. The Environmental Institute, University of Massachusetts, Amherst, MA. Publication 90-2. 77 pp.

Abstract : *
As development pressures continue to threaten Massachusetts wetlands, requests for permits to direct stormwater flows to wetland sites have been on the rise. This literature review evaluates current knowledge regarding the impacts of such use and suggests regulatory standards which could be imposed to mitigate the potential hazards to wetland ecosystems. This report consists of a review, 4 appendices, and an annotated bibliography with 65 entries.

Noss, R.F. 1983. A Regional Landscape Approach to Maintain Diversity. BioScience 33:700-706.

Abstract: *
Land managers have traditionally assumed that achieving maximum local habitat diversity will favor diversity of wildlife. Recent trends in species composition in fragmented landscapes suggest, however, that a more comprehensive view is required for perpetuation of regional diversity. A regional network of preserves,

with sensitive habitats insulated from human disturbance, might best perpetuate ecosystem integrity in the long term.

Noss, R.F. 1987. Corridors in Real Landscapes: A Reply to Simberloff and Cox. Conservation Biology 1:159-164.

Abstract: *
Habitat corridors have become popular in land-use and conservation strategies, yet few data are available to either support or refute their value. Simberloff and Cox (1987) have criticized what they consider an uncritical acceptance of corridors in conservation planning.

Any reasonable conservation strategy must address the overwhelming problem of habitat fragmentation. Although Simberloff and Cox use island analogies to illustrate advantages of isolation, these analogies do not apply directly to problems in landscape planning. Genetics also does not offer unequivocal advice, but the life histories of wide-ranging animals (e.g., the Florida panther) suggest that the maintenance or restoration of connectivity in the landscape is a prudent strategy. Translocation of individuals among reserves, considered by Simberloff and Cox a viable alternative to natural dispersal, is impractical for whole communities of species that are likely to suffer from problems related to fragmentation.

Many of the potential disadvantages of corridors could be avoided or mitigated by enlarging corridor widths or by applying ecologically sound zoning regulations. Corridors are not the solution to all our conservation problems, nor should they be used as a justification for small reserves. But corridors can be a cost-effective complement to the strategy of large and multiple reserves in real-life landscapes.

Nouri, H. 1989. Building a Better Wetland. Civil Engineering 59:45-46.

Abstract: **
Computer-operated tide gates were used to regulate water levels in the restoration of the Ballona Wetlands near Los Angeles. The restoration plan was primarily designed to create pickleweed nesting habitat for the Belding's savannah sparrow, an endangered species.

Ogawa, H. and J.W. Male. 1988. Evaluation Framework for Wetland Regulation. Journal of Environmental Management 21:95-109.

Abstract: *
Flood mitigation potential is an important aspect of wetlands, and must be considered when application for modification of a wetland has been made. The procedure presented in this paper allows regulatory agencies, particularly at the local level, to assess quickly what the effects of wetland modification of peak

streamflows might be, and to determine whether more in-depth analyses should be conducted. The approach relies on equations developed from regression analyses and watershed simulations. Results of the approach are presented for an area encompassing three river basins in eastern Massachusetts. Flood mitigation potential is an important aspect of wetlands, and must be considered when application for modification of a wetland has been made. The procedure presented in this paper allows regulatory agencies, particularly at the local level, to assess quickly what the effects of wetland modification of peak streamflows might be, and to determine whether more in-depth analyses should be conducted. The approach relies on equations developed from regression analyses and watershed simulations. Results of the approach are presented for an area encompassing three river basins in eastern Massachusetts.

Phillips, R.C. 1991. Eelgrass Research in the Pacific Northwest. Paper presented at the Annual Meeting, Pacific Northwest Chapter, Society of Wetland Scientists. April 26-27, Newport, Oregon.

Abstract: **
Author cites the need for scientific investigations in the Pacific Northwest regarding "successful" establishment of eelgrass beds (*Zostera marina*). This research should focus on the functional equivalency of transplanted eelgrass beds.

Posey, M.H. 1988. Community Changes Associated with the Spread of an Introduced Seagrass, *Zostera japonica*. Ecology 69:974-983.

Abstract: *
Species introductions have provided a valuable source of information for understanding the factors that regulate community composition. However, the effect of such introductions has often been obscured by a lack of information of distribution and abundance patterns before or during an invasion event. I examined the changes in a benthic community associated with the ongoing spread of an introduced seagrass, *Zostera japonica*, by sampling transplanted seagrass plots and established *Z. japonica* patches of known ages.

The sedimentary and faunal changes associated with *Z. japonica* were similar to those observed with native seagrass species. Mean sediment grain size declined and sediment volatile organics increased within *Z. japonica* patches. Faunal richness was higher within *Z. japonica* patches compared with adjacent unvegetated areas, and many numerically dominant species were positively associated with this introduced seagrass. However, the effects of *Z. japonica* on faunal abundance varied with both the age of a seagrass patch and site location. The introduction of this seagrass has thus changed the physical habitat as well as the richness and densities of resident fauna.

Many studies of introduced species have concentrated on direct interactions between introduced and native organisms. In contrast, the community changes associated with the introduction of *Z. japonica* emphasize the potential importance of indirect and system-level effects of introduced species on community composition.

Pritchett, D.A. 1989. Evaluation of Wetland Mitigation Projects (EvaWetMit). US EPA, Office of Cooperative Environmental Management. Doc. No. EPA/101/F-90/018.

Abstract: *
The report is part of the National Network for Environmental Management Studies under the auspices of the Office of Cooperative Environmental Management of the U.S. Environmental Protection Agency.

Wetland restoration and creation projects were examined to determine how their planning, implementation, and monitoring affected project successes. Restoration and creation was required, under Sections 404 and 309 of the Clean Water Act, as mitigation for wetland losses brought about by various forms of land development. Projects examined are limited to non-tidal palustrine wetlands, such as freshwater marshes, swamps, and seasonal pools, but examples from throughout the conterminous United State are included. In addition, guidelines and recommendations for restoration and creation projects were compiled from a survey of wetland mitigation literature and are included as a separate section of the report.

Race, M.S. 1985. Critique of Present Wetlands Mitigation Policies in the United Stated Based on an Analysis of Past Restoration Projects in San Francisco Bay. Environmental Management 9:71-82.

Abstract: *
A detailed evaluation of past wetland restoration projects in San Francisco Bay was undertaken to determine their present status and degree of success. Many of the projects never reached the level of success purported and others have been plagued by serious problems. On the basis of these findings, it is debatable whether any sites in San Francisco Bay can be described as completed, active, or successful restoration projects at present. In spite of these limited accomplishments, wetland creation and restoration have been adopted in the coastal permit process as mitigation to offset environmental damage or loss of habitat. However, because the technology is still largely experimental, there is no guarantee that man-made wetlands will persist as permanent substitutes for sacrificed natural habitats. Existing permit policies should be reanalyzed to insure that they actually succeed in safeguarding diminishing wetlands resources rather than bartering them away for questionable habitat substitutes. Coastal managers must be more specific about

project requirements and goals before approval is granted. Continued research on a regional basis is needed to advance marsh establishment techniques into a proven technology. In the meantime, policies encouraging or allowing quid pro quo exchanges of natural wetlands with man-made replacements should proceed with caution. The technology and management policies used at present are many steps ahead of the needed supporting documentation.

Race, M.S. and D.R. Christie. 1982. Coastal Zone Development: Mitigation, Marsh Creation, and Decision-Making. Environmental Management 6:317-328.

Abstract: *
Marsh creation is currently receiving wide attention in the United States as an important tool for mitigating the impacts of development in coastal wetlands. The perception that there is no net loss in valuable coastal wetlands when development is mitigated by the creation of man-made marshes can have a substantial impact on the permitting and decision-making processes. The effective result may be the trading of natural salt marshes for man-made marshes. Techniques for marsh creation were developed by the US Army Corps of Engineers to enhance and stabilize dredge spoil materials. Most research sponsored by the Corps has been directed at determining whether these goals have been accomplished. A survey of the research indicated that there is insufficient evidence to conclude that man-made marshes function like natural salt marshes or provide the important values of natural marshes. It is necessary, therefore, for decision-makers to understand the limitations of present knowledge about man-made marshes, realistically evaluate the trade-offs involved, and relegate mitigation to its proper role in the permitting process--post facto conditions imposed on developments that clearly meet state qualifications and policies.

Reed, W.C. and M.C. Heath. 1974. Saltmarsh relocation restoration in Maine. Prepared by Reed & D'Andrea, South Gardiner, ME, for the Maine Dept. of Transportation, Augusta, ME.

Abstract: *
Salt marsh restoration and relocation is examined as an alternative to marsh losses from construction activities or as a means of stabilizing erosion. Procedures developed on the coasts of Maryland and North Carolina are examined, and factors affecting the transferability of these to the Maine coast detailed. The existing literature on biological, physical, and economic considerations is reviewed, including:

1. Appropriate plant species for marsh propagation, their nutrient requirements,productivity, and intraspecies variation.
2. Location in terms of tidal influence and substrate.

3. Effect of sedimentation, erosion, ice and other physical stresses on established and newly formed marsh environments.
4. Benefits derived from salt marshes, direct and indirect.
5. Costs involved in artificial marsh propagation.

Finally, site selection criteria are discussed based on the previous review.

Rice, P.D. 1984. Habitat Suitability Index Models: Dabbling Ducks. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Optimal dabbling duck habitat is provided by wetlands with 50% cover and 50% open water. Unsatisfactory nesting conditions result from silt-covered shallows, broad mud flats, and absence of submergent vegetation in open water. Preferred wetland nesting habitat is bulrush and cattail, and preferred upland cover is tall grass and brush.]

Salvesen, D. Wetlands: Mitigating and Regulating Development Impacts. Washington D.C.: ULI-The Urban Land Institute, 1990.

Abstract: **
An introduction to wetland types, values, and functions is followed by a rundown of Federal and State Wetland Regulations, giving FL, NJ, CA, OR, MS, and MA as examples. The author then discusses mitigation strategies and gives examples of projects which have chosen different strategies. These include Avoidance, Restoration, Enhancement, and Creation.

Schroeder, R.L. 1983. Habitat Suitability Index Models: Pileated Woodpecker. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.39. 15 pp.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information

are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[In the results of a Virginia study, most Pileated Woodpeckers rested no farther than 150 m (492 ft) from water, and most nests were within 50 m (164 ft) of water. Average distance between water sources was 600 m (1969 ft). Minimum nesting area was 130 ha (320 acres).]

Shisler, J.K. 1990. Creation and Restoration of the Coastal Wetlands of the Northeastern United States. pp. 143-170. *In*: J.A. Kusler and M.E. Kentula (eds.), Wetlands Creation and Restoration: The Status of the Science. Island Press, Washington D.C.

Abstract: *
The wetlands of the coastal zone of the northeast have been managed since the colonization of the United States. Restoration work associated with mitigation of impacts has been going on in the region for over twenty years. Despite this history, there has not been an extensive evaluation of these projects to determine their success and how they function.

The mitigation process should be directed towards a management approach that is concerned with the total system instead of just the "vegetated" wetland. Goals should be based upon a wetland system's requirements within a watershed or region. The use of adjacent wetlands as models is critical in this process. Monitoring the created or restored wetlands can provide an important database which can be used in planning future projects. Goals, clearly defined in the design process, will promote meaningful evaluations.

Sinicrope, T. L., P.G. Hine, R.S. Warren, and W.A. Niering. 1990. Restoration of an Impounded Salt Marsh in New England. Estuaries 13:25-30.

Abstract: *
The restoration of a 20 ha tidal marsh, impounded for 32 yr, in Stonington, Connecticut was studied to document vegetation change 10 yr after the reintroduction of tidal flushing. These data were then compared to a 1976 survey of the same marsh when it was in its freshest state and dominated the *Typha angustifolia*. Currently, *T. angustifolia* remains vigorous only along the upland borders and in the upper reaches of the valley marsh. Live coverage of *T. angustifolia* has declined from 74% to 16% and surviving stands are mostly stunted and depauperate. Other brackish species have also been adversely effected, except

for *Phragmites australis* which has increased. In contrast, the salt marsh species *Spartina alterniflora* has dramatically expanded, from < 1% to 45% cover over the last decade. Locally, high marsh species have also become established, covering another 20% of the marsh.

Smardon, R.C. 1978. Visual-Cultural Values of Wetlands. pp. 535-544 *In*: P.E. Greeson, J.R. Clark, and J.E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. American Water Resources Association.

Abstract: *
The paper addresses the visual-cultural values, or the visual, recreational, and educational values, of inland and coastal wetlands in the United States. An "ecological aesthetics" perspective is proposed, based on evidence that information about natural and cultural processes associated with a landscape increases the aesthetic value of that landscape for the perceiver. Single significant visual-cultural values, as well as composite values, of wetlands are reviewed. The critical literature is reviewed and detailed findings are discussed for (1) wetlands in comparison to other landscapes, (2) specific types of wetlands compared to each other, (3) wetlands and their immediate surroundings, (4) wetlands and the micro-landscape within, and (5) dynamic phenomena associated with wetlands. Little substantive research concerning visual-cultural values of wetlands has been done. Existing research is restricted to the central northeastern, southern, and west coast regions of the United States. Priorities and key questions for visual-cultural wetland research are suggested.

Stuber, R.J., G. Gilbert, and O.E. Maughan. 1982. Habitat Suitability Index Models: Largemouth Bass. U.S. Dept. Int., Fish Wildl. Service. FWS/OBS-82/10.16.

Abstract: *
This document is part of the Habitat Suitability Index (HSI) Model Series (FWS/OBS-82/10), which provides habitat information useful for impact assessment and habitat management studies. Several types of habitat information are provided. The Habitat Use Information Section is largely constrained to those data that can be used to derive quantitative relationships between key environmental variables and habitat suitability. The habitat use information provides the foundation for the HSI model that follows. In addition, this same information may be useful in the development of other models more appropriate to specific assessment or evaluation needs.

[Optimum habitat consists of large, slow-moving rivers or pools (≥ 60% of habitat), relatively clear, shallow (≤ 6 m deep), with soft bottoms, some aquatic vegetation, with overwintering areas (40 to 60% of lake at least 15 m deep), and shoreline vegetation (adult largemouth bass typically fed near the vegetation). Additional optimal conditions for adult largemouth bass include cover vegetation, log debris, and brush, with cover ranging from 40 to 60% (> 60% reduced prey). Amount of cover was found to be positively correlated with the number of fry present. Optimal fry habitat contained cover from 40 to 80%. Optimal temperature for fry growth ranged from 27 to 30 °C (80.6 to 86°F).]

Thom, R.M., E.O. Salo, C.A. Simenstad, J.R. Cordell, and D.K. Shreffler. 1987. Construction of a wetland system in the Puyallup River Estuary, Washington. Paper presented at the Eighth Annual Meeting of the Society of Wetland Scientists, Seattle, WA.

Abstract: *
A 3.9 ha estuarine wetland system was constructed in 1985-1986 in the tidally influenced portion of the Puyallup River. The system consists of channels, mudflats, a sedge marsh, a swamp, a cattail marsh, trees and a grassland. Monitoring studies showed the system supported outmigrating juvenile salmon, shore birds, waterfowl and raptors.

Tourbier, J. and R. Westmacott. 1980. Water Resources Protection Measures in Land Development - A Handbook (Revised Edition). Water Resources Center, University of Delaware, Newark, Delaware, 210 pp.

Abstract : *
This handbook contains descriptions of measures in urban development to prevent, reduce or ameliorate potential problems that would otherwise adversely affect water resources. These problems consist of runoff increases and decreases in infiltration and a greater degree of erosion and sedimentation, flooding, runoff pollution and discharge of sewage effluent. Issues have been analyzed individually in the Christina River Basin. Each measure is described and site characteristics to which it is applicable identified. The application, advantages and disadvantages, design criteria and outline specifications, cost guidelines and maintenance, and legal implications of each measure are individually covered.

Wakeley, J.S. 1989. Mitigation Database: Tracking Mitigation Activities in the Section 404 Permitting Program. Miscellaneous Paper EL-89-8, US Army Engineer Waterways Experiment Station. Vicksburg, MS.

Abstract: *
This report presents a recommended list of variables for development of a mitigation database by US Army Corps of Engineers (CE) Regulatory offices. Uses of the database include periodic review of CE Regulatory program mitigation efforts, evaluation of trends in permitted wetland activities, and preparation of responses to public or agency inquires. Depending upon the level of implementation chosen, the mitigation database contains information on wetland

type and acreages impacted, restored, or created; the spatial distribution of projects; effects of the permit review process in lessening potential impacts; wetland functions and values considered in permit decisions; mitigation goals; and restoration or compensation methods.

Wentz, W.A., R.L. Smith, and J.A. Kadlec. 1974. State-of-the-Art Survey and Evaluation of Marsh Plant Establishment Techniques: Induced and Natural, vol. 2, A Selected Annotated Bibliography on Aquatic and Marsh Plants and Their Management. Prepared for the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi by the School of Natural Resources, University of Michigan, Ann Arbor, Michigan.

Abstract: *
The 703 references listed in this volume were collected for the investigation of marsh and aquatic plant establishment which is reported in Volume I, Report of Research, of this report. The purpose of this bibliography is to make available an annotated listing of references which were not cited in Volume I. Although the bibliography does not represent an exhaustive review of the literature, it does provide an extensive survey of the pertinent references on the ecology and management of aquatic and marsh plants. The references selected for this bibliography emphasize studies useful to researchers and managers. In accordance with the focus of Volume I, this volume concentrates on coastal Great Lakes, and riverine marshes.

Williams J.D. and C.K. Dodd, Jr. 1978. Importance of Wetlands to Endangered and Threatened Species. pp. 565-575. *In:* P.E. Greeson, J.R. Clark, and J.E. Clark (eds.), Wetland Functions and Values: The State of Our Understanding. American Water Resources Association.

Abstract: *
The importance of wetland habitats to certain endangered and threatened plants and animals of the United States is reviewed and examples of endangered and threatened reptiles, amphibians, fishes, and birds dependent on wetlands are discussed. The role of the American alligator in shaping some wetland habitats is greater than its commercial value. The status of wetland habitats in desert areas of the southwestern United States is examined and Ash Meadows, Nevada, is used as an example to illustrate the precarious nature of these habitats. On a national basis, the percentage of endangered and threatened species dependent on wetlands is presented by major taxonomic groups. Without increased protection of wetland habitats, many of our endangered and threatened species may disappear before the end of the century.

Winter, T.C. 1988. A Conceptual Framework for Assessing Cumulative Impacts on the Hydrology of Nontidal Wetlands. Environmental Management 12:605-620.

Abstract: *
Wetlands occur in geologic and hydrologic settings that enhance the accumulation or retention of water. Regional slope, local relief, and permeability of the land surface are major controls on the formation of wetlands by surface-water sources. However, these landscape features also have significant control over groundwater flow systems, which commonly play a role in the formation of wetlands. Because the hydrologic system is a continuum, any modification of one component will have an effect on contiguous components. Disturbances commonly affecting the hydrologic system as it relates to wetlands include weather modification, alteration of plant communities, storage of surface water, road construction, drainage of surface water and soil water, alteration of groundwater recharge and discharge areas, and pumping of groundwater. Assessments of the cumulative effects of one or more of these disturbances on the hydrologic system as related to wetlands must take into account uncertainty in the measurements and in the assumptions that are made in hydrologic studies. For example, it may be appropriate to assume that regional groundwater flow systems are recharged in uplands and discharged in lowlands. However, a similar assumption commonly does not apply on a local scale, because of the spatial and temporal dynamics of groundwater recharge. Lack of appreciation of such hydrologic factors can lead to misunderstanding of the hydrologic function of wetlands within various parts of the landscape and mismanagement of wetland ecosystems.

Wolf, R.B., L.C. Lee, and R.R. Shartz. 1986. Wetland Creation and Restoration in the US from 1970 to 1985: An Annotated Bibliography. Wetlands 6:1-88.

Abstract: **
This bibliography deals with the creation of new and the restoration of disturbed salt and freshwater wetlands in the United States since 1970. The authors aim was to provide wetland scientists and regulatory agencies with an index for identifying and locating publications useful in planning new projects or reviewing old ones. In selecting projects, they emphasized site engineering and plant propagation. Therefore, numerous articles that discuss preparing the site for natural or artificial revegetation, and transplanting and seeding of vegetation, are included in the 304 reports cited. However, articles concerning more minor habitat adjustments and, for example, lake or reservoir management for wildlife or waterfowl, are not included.

Documents are arranged alphabetically by senior author. A full citation and brief description of the problem or topic discussed is included for each one. National Technical Information Service (NTIS, Springfield, VA 22161) order numbers are

provided for publications available through that office. Following the citations are indices arranged by plant species, subject, and state.

Reports of wetland restoration and creation projects from more than 30 states are cited. In these articles, all major aspects of wetland construction are described in detail. Such topics as site selection; planning; engineering and design; seeding; plant material selection, harvest,storage, and transplanting; fertilization requirements, cost and labor estimates; and maintenance requirements are included for marsh, riparian, and littoral zone development. Detailed directions for propagating about 150 plant species can be found. Additionally, more basic questions are addressed, such as the value of wetlands, whether artificial or restored wetlands approximate natural, and how wetlands should be regulated. Several bibliographies, project surveys, and literature reviews are included.

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Abstract: *
Despite loss of over 50% of the wetlands in the contiguous United States, there is a continuing pressure to use wetlands for immediate economic gain. Functional values that are nearly perpetual (self-maintaining) are rarely considered, and the complexity, integrity, and uniqueness of natural wetlands are undervalued. It is commonly assumed that wetland losses can be mitigated by restoring or creating wetlands of equal value. Some feel that replication is not always necessary if certain functions are replaced; others, including most wetland scientists, recognize that duplication is impossible and simulation is improbable. All would agree that we need substantially more information about what functions are being lost and how to replace them. This overview highlights the topics for which information needs are greatest and provides a research strategy to: a) improve wetland restoration/creation efforts, b) determine the degree to which constructed systems can replace lost functions, and c) determine the potential for persistence (resilience) of restored and constructed wetlands.

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